SHAPE OPTIMIZATION OF SUPERCAVITATING PROJECTILES UNDER WATER

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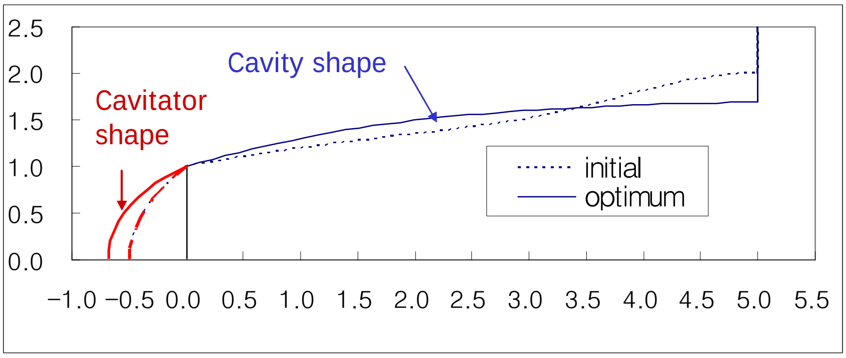
Shape optimization techniques were used to obtain the solution of supercavitating flow, which occurs when an underwater projectile travels at high speeds (200 mph). Supercavitation is a phenomenon where a cavity (filled with vapor) is generated around the projectile. When designing such a projectile for minimum drag it is necessary to have only the nose of the projectile wetted, while the rest of it is enclosed in the cavity. Therefore, the shape of the cavitator, which is the nose of the projectile, is significant because it determines not only the cavity shape, but also the magnitude of the drag force. Since the projectile is required to operate under high speeds, any reduction in the drag force would result in reduced propulsion requirements. In this research, shape optimization technique is employed to determine the optimum cavitator shape which minimizes drag, while satisfying certain operating conditions. Shape optimization technique is also used to solve the potential flow problem for any given cavitator, which is a free boundary value problem having the cavity shape as unknown a priori. Analytical sensitivities were also derived for various shape parameters in order to implement a gradient based optimization algorithm. In this research, a methodology is developed for efficient cavitator shape optimization, in which the cavity and cavitator shapes were determined simultaneously.

A parametric study was performed to compare the obtained solution with results from the literature, Uhlman (2002). Current results match closely with both the theoretical and Uhlman's results, who considered a generic re-entrant jet cavity and boundary element method for the analysis. The cavitator optimization is then carried out for a number of cavity lengths using an arbitrary cavitation number of $\sigma = 0.2$. A spline function was used to model the cavity shape and a rational quadratic function for the cavitator shape. The optimum shape corresponding to a cavity length of 5 units is shown in the following figure. The optimization results showed that as the required cavity length increases, the drag coefficient also increases, changing the nose from flat-long to short-triangular shape. Though these optimum results were for a specific case, additional designs could be explored for different constraints.



References

[1] J.S. Uhlman, "A Note on the Development of a Nonlinear Axisymmetric Reentrant Jet Cavitation Model," Paper submitted, 2002.